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VERTICILLIUM WILT (HADROMYCOSIS) OF COTTON IN THE SAN JOAQUIN VALLEY OF CALIFORNIA

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INTRODUCTION

A cotton wilt disease, caused by a soil fungus identified by Shapovalov and Rudolph as *Verticillium albo-atrum* Reinke and Berth.,¹ has appeared in the San Joaquin Valley of California. It was first observed in California by the writers in 1927, when an infected plant was brought to the United States Cotton Field Station at Shafter, Calif., by a rancher from the Wasco district. Only a small area of infection was found at that time, and there was no further report of the disease until the fall of 1929, when it was observed to be prevalent in a number of fields within an area of about 20 miles in extent near Shafter and Wasco. The owners of these fields stated that they noticed only slight evidence of the disease in 1928. In 1930 the disease was found in many places in the San Joaquin Valley, occurring in several locations in Madera, Kings, Tulare, and Kern Counties. The most severe infestations noted in 1929 and 1930 were in Kern County in fields near Wasco and Shafter. How long the disease has been in the San Joaquin Valley unobserved is only speculative, but it was most likely present long before it was observed in 1927, otherwise it must be assumed that the disease spreads rapidly and is likely to become general.

DESCRIPTION OF SYMPTOMS

The first outward symptom of the disease is a distinct mottling of the leaves with pale yellowish irregular areas appearing at the margins and between the principal veins, showing a deficiency of chlorophyll. These symptoms occur in early summer, usually on the lower leaves, spreading to the middle and upper leaves of the plant later in the season. The yellow areas gradually become paler and more whitish and necrotic, finally dying and turning brown. Typical specimens of leaf injuries are shown in Plate 1. At the time or even before the yellow discoloration appears in the leaves, a longitudinal cut into the wood at the base of the main stalk may reveal a slight

¹ SHAPOVALOV, M., and RUDOLPH, B. A. VERTICILLIUM HADROMYCOSIS (WILT) OF COTTON IN CALIFORNIA. U. S. Dept. Agr., Bur. Plant Indus. Plant Disease Rptr. 14:9. 1930. [Mimeographed.]

browning of the vascular system, which later becomes very pronounced. Plate 2 shows typical longitudinal sections of the main stalk of a diseased plant. In the late summer, when the effect of the disease is most apparent, the leaves of badly diseased plants present a mosaic pattern of rust-colored dead areas with yellowish margins, lying between narrow strips of green, bordering the principal veins. Later the leaves fall, and the plant may become defoliated except for a few small leaves at the top and at the ends of the branches, as shown in Plate 3.

POSSIBLE SOURCES OF INFECTION

As pointed out by Shapovalov and Rudolph,² there is some evidence that the *Verticillium* fungus was introduced into the soil with potatoes, which are grown extensively in many localities where the disease has occurred. In some cases, however, the disease appeared in fields and on ranches where there is no record of potatoes ever having been grown, indicating other sources of infection or a relatively easy transfer of the fungus from one soil area to another. One of the worst infested fields in the valley, consisting of 40 acres, had been planted to alfalfa continuously previous to 1927 with but one exception, when a few acres were planted to muskmelons. Cotton was grown in this field for the first time in 1927, and the disease was first noticed in the field in 1928. The owner reports that a single garden apricot tree infected with a disease that showed symptoms very similar to *Verticillium* wilt of cotton was removed from a location near this field in 1927. It is possible that this single tree was a source of infection. Shapovalov and Rudolph report that they have repeatedly isolated the *Verticillium* fungus from deciduous fruit trees in California.

The disease has occurred in several widely separated plots at the United States cotton field station on which complete records have been kept of the crops grown since the station was established in 1921 on desert land. Two of these plots are in a new addition that was brought into cultivation in 1926 and have been planted to cotton only. Other plots showing outbreaks of the disease have been planted to sorghums, and winter and summer legumes have been used as cover crops in rotation with cotton. Potatoes, deciduous fruit trees, melons, and miscellaneous vegetables are grown on other plots at the station, which consists of 80 acres.

There is no evidence that the disease is spread with the seed. Seed collected in 1929 from badly infected cotton plants and planted in 1930 on disease-free soil produced normal, healthy plants. Further studies along this line are in progress.

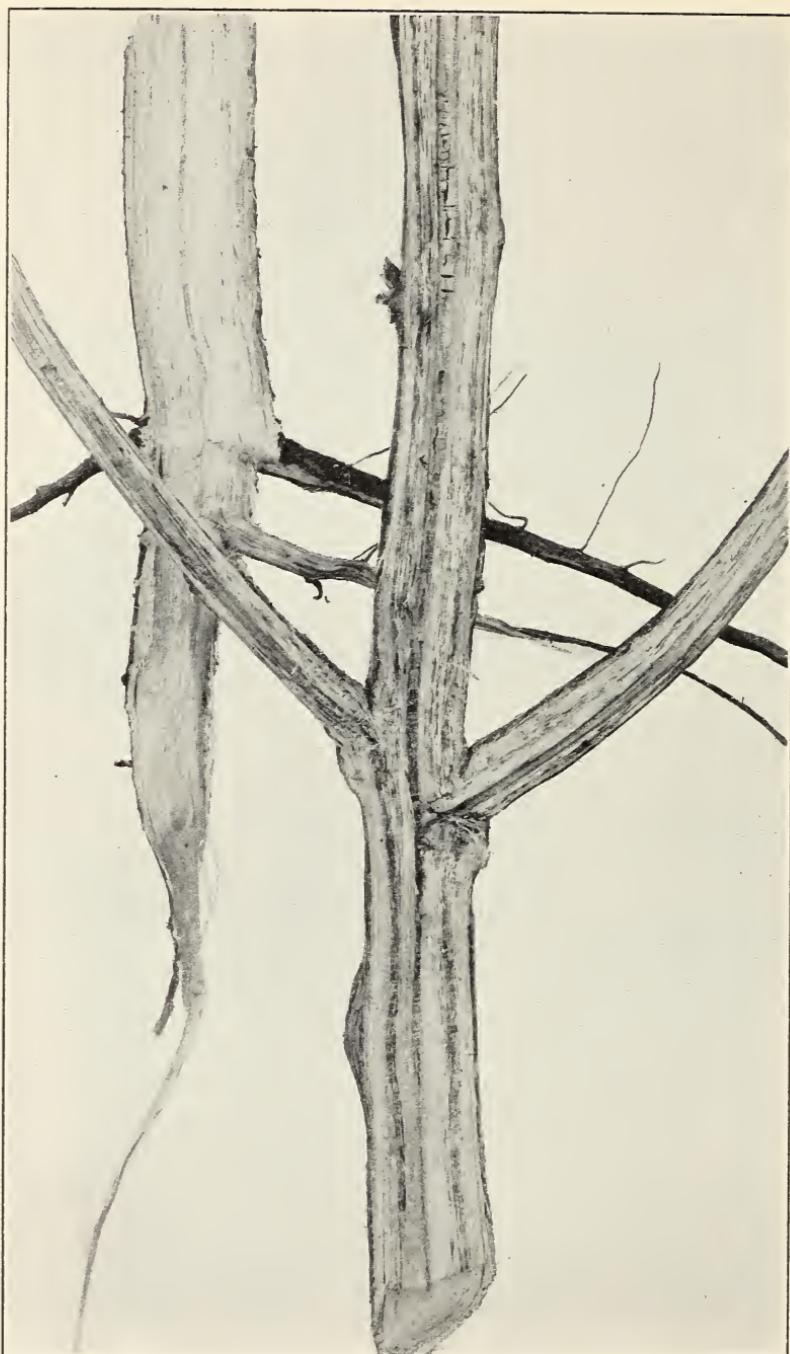
EFFECTS UPON DIFFERENT VARIETIES

In 1930 the disease appeared in an area of about 3 acres on which was planted a variety test containing Acala, Mebane, Delfos, and Pima (Egyptian) cottons, arranged in 4-row comparisons. Also a cooperative series was planted containing many of the popular varieties of the Cotton Belt, 48 in all, in single rows. One plant in the row of College No. 1 and one plant in the row of D. P. L. 4-8 were the first plants observed to show symptoms of the disease in the

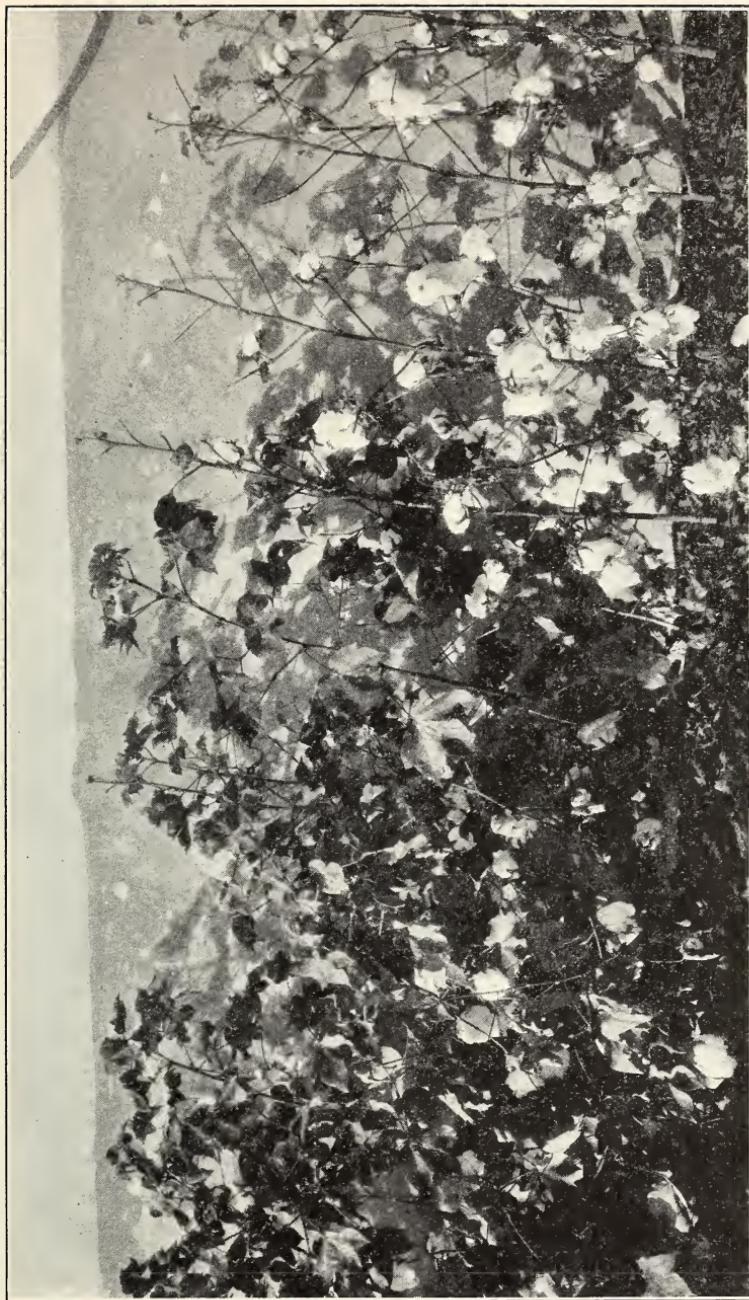
² SHAPOVALOV, M., and RUDOLPH, B. A. Op. cit.



Cotton leaves showing typical symptoms of *Verticillium* wilt disease. The dead areas are brown with pale yellowish margins



Longitudinal sections of cotton stalk showing typical discoloration of the vascular system of a plant infected with *Verticillium* wilt



The late-season appearance of plants infected with *Verticillium* wilt is shown by the diseased plants at the right in comparison with normal plants at the left. Note that the diseased area appears to end abruptly

cooperative series planting, but scattering plants of Mebane, Acala, and Delfos in the variety test were observed at the same time to show about equally pronounced symptoms. These observations were made July 2.

The number of plants showing symptoms of the disease increased rapidly during July and August, and none of the varieties except Pima showed any resistance. The three blocks of Pima plants in the variety test remained practically normal throughout the season, showing only mild disease symptoms on some of the old leaves in September, while intervening blocks of Acala plants were severely affected and began showing definite disease symptoms early in July. In a final survey, made in December, the stalks were split near the base and examined for the characteristic brown discoloration of the vascular system. These observations revealed that most of the Pima plants in the infected area were diseased even though they showed no conspicuous symptoms externally.

IMPORTANCE

Few growers made any particular note of this disease until it became quite severe in their fields. This is probably because of the fact that it usually becomes noticeable only on the older plants, and unless very prevalent it is no doubt attributed to a drying out of the plant at maturity, particularly as many of the farmers make a practice of not irrigating after the middle or end of August. So far as observed, the disease does not seem to be affected by irrigation practices.

A farmer in the Wasco district, who had one of the most severely diseased fields, estimated that the disease reduced his yield one-third on a 40-acre field in 1929, for which reason he planted the land to alfalfa in 1930. As the soil areas infested with the *Verticillium* fungus occurred in very irregular and scattered patches, it was not possible to find adequate blocks for yield comparisons. In an effort to find some indication of the effect of the disease on yields, counts of open and unopen bolls on healthy and diseased plants were made November 18, 1930, at three locations on the United States Cotton Field Station. (Table 1.)

TABLE 1.—*Open and unopen bolls on healthy and diseased plants at three locations on the United States Cotton Field Station, Shafter, Calif., November 18, 1930*

Location and plants	Open bolls	Unopen bolls	Total	Excess of yield of healthy over diseased plants
	Number	Number	Number	Per cent
No. 1: 6 consecutive healthy plants.....	139	40	179	61.2
6 consecutive diseased plants.....	109	2	111	-----
No. 2: 10 consecutive healthy plants.....	202	50	252	20.6
10 consecutive diseased plants.....	198	11	209	-----
No. 3: 14 consecutive healthy plants.....	241	82	323	9.5
14 consecutive diseased plants.....	273	22	295	-----

In each case the counts were made on healthy and diseased plants spaced approximately the same distance apart in the rows. In counting unopened bolls, only large mature bolls that would open at or

before the first killing frost were included. It will be noted that the diseased plants carried very few unopened bolls. They were practically defoliated and presented the appearance of very severely stressed plants, on which bolls open prematurely.

COMPARISON WITH FUSARIUM WILT

Verticillium wilt is not to be confused with Fusarium wilt of cotton, which is widely distributed throughout the Cotton Belt from Virginia to Texas. In Fusarium wilt, as described by Gilbert,³

certain kinds of dwarfing of the main stem are likewise characteristic of wilt, particularly a reduction in the length and a shortening of the distance between the branches. * * * The disease may kill the plants in early May, or its first indication may be the sudden wilting and death of practically mature plants in mid-September.

According to Shapovalov and Rudolph, Verticillium wilt of cotton has been reported from Virginia, Tennessee, and Arkansas. No dwarfing effect of the disease has as yet been noticed in California. The progress of the disease in a plant appears to be gradual, and the plants do not die early. In fact, as observed thus far, few plants have been killed by the disease in California, and these only late in the summer. When cotton is continued on soil that becomes more heavily infested with the Verticillium fungus, greater mortality may be expected. The disease is accompanied by a characteristic discoloration of the leaves, and only a few plants have been found showing wilt without this typical leaf discoloration. A point of similarity between Verticillium wilt and Fusarium wilt is the discoloration of the interior of the stems or roots. In Fusarium wilt this discoloration of the vascular system may be so pronounced that the disease is sometimes called black root.

Verticillium wilt appears less virulent than Fusarium wilt and may not cause general damage to cotton in California, but its presence must be recognized and studies should be made of its growth and spread, and possible methods of control should be sought.

POSSIBLE CONTROL

Very little is known at present of the spread and virulence of Verticillium wilt of cotton under California conditions. The fungus is soil borne and may be very difficult to control or eradicate, because of the many host plants. If the disease becomes general in California it may be necessary to resort to the breeding and use of resistant strains of cotton and to special rotations with disease-resistant crops. No definite methods of control are offered at this time, but it is suggested that rotations with alfalfa or some grain crops may be a practical means of avoiding crop losses.⁴

Studies are now in progress to determine the rate of spread of the fungus in infested soil areas and the methods of distribution that cause new outbreaks. Also, a series of selections has been made for disease resistance. These progenies are being grown on heavily infested soil in an effort to develop disease-resistant plants.

³ GILBERT, W. W. COTTON WILT AND ROOT-KNOT. U. S. Dept. Agr. Farmers' Bul. 625, 21 p., illus. 1914.

⁴ A discussion of the relative susceptibility of many plants to *Verticillium hadromycosis* is given in the following publication:
RUDOLPH, B. A. VERTICILLIUM HADROMYCOSIS. Hilgardia 5: [197]-360, illus. 1931.

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